



**FINAL REPORT
OF THE
SPACE SHUTTLE
PAYLOAD PLANNING WORKING GROUPS**

COMMUNICATIONS & NAVIGATION

MAY 1973

**NATIONAL AERONAUTICS & SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND 20771**

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GLOSSARY

AAFE	Advanced Applications Flight Experiments
ATS-F, F&G, H&I	Applications Technology Satellites
C&N	Communications and Navigation
CTS	Communications Technology Satellite
CW	Continuous Wave
DNSS	Defense Navigation Satellite System
DOC	Department of Commerce
DOD	Department of Defense
DOT	Department of Transportation
DWS	Disaster Warning Satellite
EFI	Electromagnetic Field Intensity
ELT	Emergency Locator Transmitter
FAA	Federal Aviation Administration
FET	Field Effect Transistor
GHz	Giga (10^9) hertz
IFR	Instrument Flight Rules
LDRL	Laser Data Relay Link
MHz	Mega (10^6) hertz
PN	Pseudo-random Noise
R&D	Research and Development
RFI	Radio Frequency Interference
SATS	Small Applications Technology Satellite
S/C-S/C	Spacecraft to Spacecraft
STADAN	Space Tracking and Data Acquisition Network
STS	Shuttle Transportation System
TDRS	Tracking and Data Relay Satellite
USCG	U. S. Coast Guard
VFR	Visual Flight Rules
VSWR	Voltage Standing Wave Ratio
WARC	World Administrative Radio Conference

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FOREWORD*

In January 1972 the United States decided to develop a new space transportation system, based on a reusable space shuttle, to replace the present expendable system.

By January 1973 planning had progressed to the point that through the European Space Research Organization (ESRO) several European nations decided to develop a Space Laboratory consisting of a manned laboratory and a pallet for remotely operated experiments to be used with the shuttle transportation system when it becomes operational in 1980.

In order to better understand the requirements which the space transportation must meet in the 80's and beyond; to provide guidance for the design and development of the shuttle and the spacelab; and most importantly, to plan a space science and applications program for the 80's to exploit the potential of the shuttle and the spacelab, the United States and Europe have actively begun to plan their space programs for the period 1978-1985, the period of transition from the expendable system to the reusable system. This includes planning for all possible modes of shuttle utilization including launching automated spacecraft, servicing spacecraft, and serving as a base for observations. The latter is referred to as the sortie mode. The first step in sortie mode planning was the Space Shuttle Sortie Workshop for NASA scientists and technologists held at the Goddard Space Flight Center during the week of July 31 to August 4, 1972. For the purposes of that workshop, shuttle sortie missions were defined as including those shuttle missions which employ observations or operations (1) from the shuttle itself, (2) with subsatellites of the shuttle, or (3) with shuttle deployed automated spacecraft having unattended lifetimes of less than about half a year.

In general the workshop was directed towards the education of selected scientific and technical personnel within NASA on the basic capabilities of the shuttle sortie mode and the further definition of how the sortie mode of operation could benefit particular disciplines. The specific workshop objectives included:

- Informing potential NASA users of the present sortie mode characteristics and capabilities
- Informing shuttle developers of user desires and requirements
- An initial assessment of the potential role of the sortie mode in each of the several NASA discipline programs
- The identification of specific sortie missions with their characteristics and requirements

*Reprinted from the volume entitled "Executive Summaries".

- The identification of the policies and procedures which must be changed or instituted to fully exploit the potential of the sortie mode
- Determining the next series of steps required to plan and implement sortie mode missions.

To accomplish these objectives 15 discipline working groups were established. The individual groups covered essentially all the space sciences, applications, technologies, and life sciences. In order to encourage dialogue between the users and the developers attendance was limited to about 200 individuals. The proceedings were, however, promptly published and widely distributed. From these proceedings it is apparent that the workshop met its specific objectives. It also generated a spirit of cooperation and enthusiasm among the participants.

The next step was to broaden the membership of the working groups to include non-NASA users and to consider all modes of use of the shuttle. To implement both objectives the working group memberships were expanded in the fall of 1972. At this time some of the working groups were combined where there was appreciable overlap. This resulted in the establishment of the 10 discipline working groups given in Attachment A. In addition European scientists and official representatives of ESRO were added to the working groups. The specific objectives of these working groups were to:

- Review the findings of the GSFC workshop with the working groups
- Identify as far as possible the missions (by mode) that will be required to meet the discipline objectives for the period 1978 to 1985
- Identify any new requirements or any modifications to the requirements in the GSFC report for the shuttle and sortie systems
- Identify the systems and subsystems that must be developed to meet the discipline objectives and indicate their priority and/or the sequence in which they should be developed
- Identify any new supporting research and technology activity which needs to be initiated
- Identify any changes in existing procedures or any new policies or procedures which are required in order to exploit the full potential of the shuttle for science, exploration and applications, and provide the easiest and widest possible involvement of competent scientists in space science
- Prepare cost estimates, development schedules and priority ranking for initial two or three missions

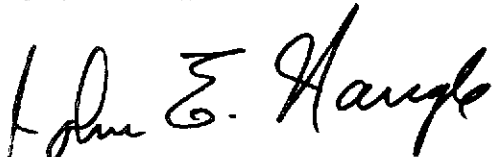
In order to keep this planning activity in phase with the shuttle system planning the initial reports from these groups were scheduled to be made available by the spring of 1973. It was also felt necessary that the individual working group activities be coordinated both between the groups and with the shuttle system planning. As a result, the steering group given in Attachment B was established.

Early in 1973, NASA and the National Academy of Sciences jointly decided that it would be appropriate for a special summer study to review the plans for shuttle utilization in the science disciplines. This summer study has now been scheduled for July 1973. It is anticipated that the results of the working group activities to date will form a significant input into this study.

In the following sections of the summary document are the executive summaries of each of the working group reports. While these give a general picture of the shuttle utilization plan, the specific plan in each discipline area can best be obtained from the full report of that working group. Each working group report has been printed as a separate volume in this publication so that individuals can select those in which they are particularly interested.

From these working group reports it is apparent that an appreciable effort has been made to exploit the full capability of the shuttle. It is, however, also apparent that much work remains to be done. To accomplish this important work, the discipline working groups will continue.

Finally it is evident from these reports that many individuals and groups have devoted appreciable effort to this important planning activity. I would like to express my appreciation for this effort and stress the importance of such activities if we are to realize the full potential of space systems in the 1980s.

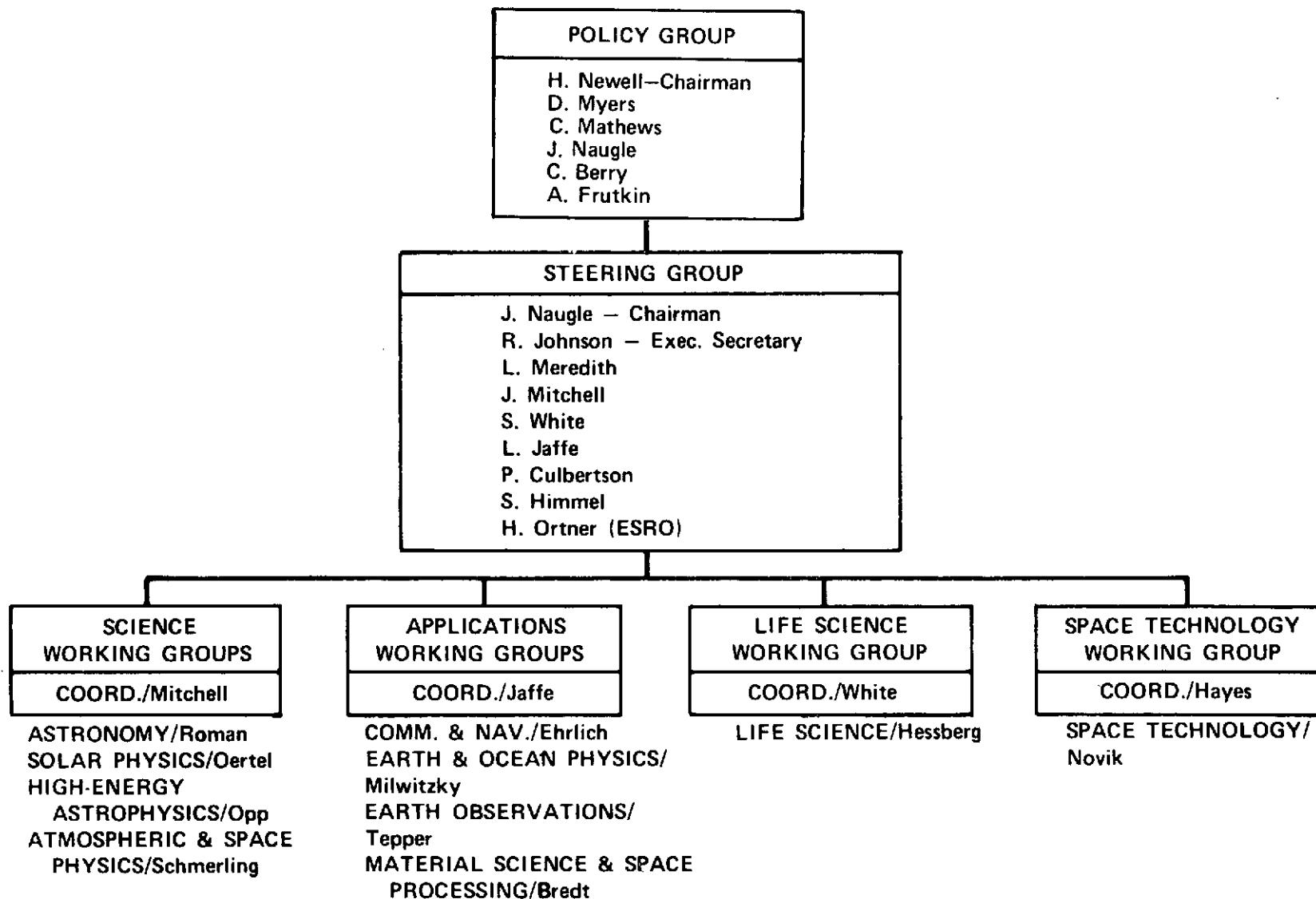
A handwritten signature in dark ink, reading "John E. Naugle". The signature is written in a cursive, flowing style with a large initial "J".

John E. Naugle, Chairman
NASA Shuttle Payload Planning
Steering Group

LIST OF WORKING GROUPS

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2.	ATMOSPHERIC & SPACE PHYSICS	Dr. E. Schmerling (HQ)	Mr. W. Roberts (MSFC)
3.	HIGH ENERGY ASTROPHYSICS	Dr. A. Opp (HQ)	Dr. F. McDonald (GSFC)
4.	LIFE SCIENCES	Dr. R. Hessberg (HQ)	Dr. D. Winter (ARC)
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NASA AD HOC ORGANIZATION FOR SHUTTLE PAYLOAD PLANNING



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REPORT OF THE
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COMMUNICATIONS & NAVIGATION WORKING GROUP

EXECUTIVE SUMMARY

The Space Shuttle Transportation System offers the Communications and Navigation (C&N), Research and Development (R&D) and operational organizations new opportunities for developing advanced space technologies and systems in a more timely manner and at lower cost than present systems.

The Shuttle Sortie Laboratory, with its capability of carrying a maximum weight of 30,000 kilograms into a low-earth orbit, will provide a new and versatile platform to conduct certain communication and navigation experiments such as: development of large, deployable antennas for future NASA missions and for communications satellites; laser communications both to another satellite for spacecraft to spacecraft (s/c-s/c) communication transfer and direct to ground stations; and radio frequency interference mapping of terrestrial noise sources. The Sortie mode also facilitates ease of comparative test evaluation between alternative subsystems (such as antenna deployment schemes) and components prior to a commitment to an automated satellite. This will provide the C&N community with a platform to conduct in-space tests of new technology prior to commitment to an automated spacecraft. The Sortie's ability to return experiments to Earth provides for an evaluation of space environmental effects on certain communications equipment (e.g., parabolic antennas).

Although the initial Laboratory mission of seven days duration will meet many of the experiment needs, early implementation of 30-day missions will provide the experimenters with more data for statistical analysis. This will be desirable in radio interference, and laser and millimeter wave propagation experiments. Prior to these longer missions, reflays of these experiments on subsequent Laboratory flights will be desired.

All C&N automated payloads considered in the 1979-1990 time period require placement into the geostationary orbit. The large weight carrying capability of the Shuttle, its multiple payload ability, and its lower cost per pound of experiment placed into space, provides an opportunity for increased launches of space vehicles to obtain the needed technical data and to develop the required communications and related space technology. The Shuttle Astronauts may be able to perform some satellite checkout in low orbit, make some subsystem adjustments, and calibrate instrumentation to ensure successful operation before leaving the satellite unattended. To provide reliable launch services and to realize the economics of the new Shuttle Transportation System (STS), the

Tug should be made available to these payloads as early as practical, and the Tug should be capable of delivering at least a 1,360 kilogram spacecraft to the geostationary orbit. In order to realize the potential capabilities of the STS to perform in-orbit checkout, in-orbit repair and retrieval of communications and navigation satellites, studies of future spacecraft configurations are required.

In conclusion, the Shuttle Sortie Laboratory, pallet design and mission profile appear capable of providing a practical means for meeting many C&N experiment data gathering needs and for developing new space technology. The Shuttle plus Tug system can place into the desired geostationary orbit all of the C&N automated payloads considered for the first shuttle decade. These missions can gather the long term data needed and develop the space systems which may lead to eventual operational space applications by new user groups, and will increase the reliability and lower the cost to present day users of space systems.

REPORT OF THE COMMUNICATIONS AND NAVIGATION WORKING GROUP

INTRODUCTION

The present stable of space transportation systems have successfully placed many active, transponding, communications satellites into a variety of earth orbits beginning in October, 1960 with the U. S. Army's Project Courier experimental spacecraft launched by a Thor vehicle into a 1,200 x 1,000 kilometer orbit, and culminating in the Intelsat IV series of 1,360 kilogram operational spacecraft for commercial international communications launched by Atlas-Centaurs into the geostationary orbit (36,000 kilometers). Communications satellite systems research and development organizations are continuing to use automated spacecraft of NASA's Applications Technology Satellite series and various Department of Defense (DOD) satellite (Lincoln Experimental Satellites) to test new systems and technology. The smallest of the present launch vehicles, Scout, has placed numerous R&D navigation satellites, called Transit, into orbit for the DOD. An operational system is now available to military and non-military users. Improved navigation satellite technology and systems are being pursued by NASA in the ATS-F project, and by the DOD in the Timation series of R&D satellites.

The planned Shuttle Transportation System will provide the research and development organizations and operating groups with new capabilities for experimenting with and advancing communications and navigation satellite technology. The Shuttle's Sortie mission can carry 30,000 kilograms into a low-earth orbit. This will provide the C&N community with a platform to conduct in-space tests of new technology prior to commitment to an automated spacecraft. The Shuttle in conjunction with the Tug system will be able to place a 3,600 kilogram communications or navigation spacecraft into the geostationary orbit at a lower cost than can be accomplished by the present launch vehicle stable. This system will also be able to retrieve malfunctioning geostationary satellites and bring them back to earth for repair and reuse, or perform some types of in-orbit service.

GENERAL

This report of the Communications and Navigation Shuttle Payload Working Group is based upon meetings held prior to the NASA decision in January 1973 to phase out communications satellite activities. Therefore, the R&D and prototype operational spacecraft missions described as being conducted by NASA, will not be conducted by the agency. But these missions were considered desirable by the Working Group to advance communications and navigation satellite systems

and technology for future needs. The assumption is made that these recommended space flight missions have valid objectives that are likely to be justified by other government agencies or private aerospace organizations.

GOALS & OBJECTIVES

The goal of the C&N discipline during the era of the Space Shuttle Transportation System will be to increase the use of space systems and develop new space capabilities for providing communication and navigation services to the user community in the 1980's and 90's. To meet this goal the government, working in conjunction with the user, will need to assess and quantify, to the extent possible, requirements for new and expanded communications, navigation, traffic control and search and rescue services. It must develop the systems concepts that will facilitate the application of the space technology for improving existing techniques of communicating voice and data information between earth, air and space terminals; and for improving the present and planned navigation, traffic control and position fixing methods of aircraft, terrestrial, vehicles and spacecraft.

The critical technology required by satellite systems to provide these services must be determined. Planning for best use of the frequency spectrum and of the synchronous orbit will be required so that the satellites needed to operate in the geostationary orbit neither interfere with each other nor with existing terrestrial communications services using the same frequencies.

Finally, the government must assist the user community in developing the capability to define and conduct communications and navigation experiments using space systems. This will provide operating experience and determine total systems feasibility (Ground and Space Segments). An example would be future information networking satellite systems.

PROGRAM ELEMENTS

The NASA Communications and Navigation Program is divided into three major elements:

- Communications Systems R&D
- Special Communications Applications
- Navigation/Traffic Control.

COMMUNICATIONS SYSTEMS R&D

Communications Systems R&D is concerned with understanding and developing system concepts and critical technologies which are common to the needs of a broad spectrum of communications users. The general characteristics for these systems and technologies are derived from user's needs, either on a technical or cost effective basis. Many of the communications technologies are high-risk advanced developments which commercial organizations or non-R&D oriented government agencies may not undertake. Within this area NASA will provide technical information and support on communications satellite systems to other government agencies as part of its responsibility under the communications satellite act of 1962: developing the data base necessary to characterize and specify the communications link performance in frequency bands of interest to the users; assessing the capability of allocated frequency spectrum and available orbital spacing to support future communication satellite missions; and performing component and systems technology developments, such as high-power radio frequency (RF) space equipments, multibeam antennas and signal/data processing techniques needed for meeting the future requirements of communications users. The ATS-H&I satellite is a planned new spacecraft project presently in the definition study stage. It will develop the required high power RF and antenna technology to permit simultaneous multi-user experimentation in transferring cultural, educational and health care information to remote regions. The Small Applications Technology Satellite (SATS) Program is a proposed activity that will permit quick reaction flight tests of critical technology and systems needed for future NASA and user missions. An early candidate for the SATS Program is a Radio Frequency Interference (RFI) survey experiment to assist in the design of future tracking and data relay satellite systems and of low-altitude, earth orbiting satellites.

The Shuttle Sortie will provide easy access to space to perform these experiments with the same flexibility that aircraft provide. Man's presence will help to produce the greatest amount of information from brief space flights.

SPECIAL COMMUNICATIONS APPLICATIONS

Special communications applications encompasses the application of those system concepts and technologies which offer solutions to particular requirements of identifiable user needs. It identifies user interest for improved communications-satellite and/or terrestrial methods, conducts studies which quantify requirements and develops system concepts appropriate to these requirements. NASA will assist these users to define and conduct experiments. ATS-F&G is the on-going multi-user communications and navigation satellite to develop technology and

conduct user oriented experiments in such areas as: TV broadcast distribution with India, satellite tracking and data relay for NASA's Office of Tracking & Data Acquisition, and a navigation experiment for locating air and marine vehicles in conjunction with the Federal Aviation Administration/US Coast Guard (FAA/USCG) and Maritime Administration.

The CTS is a NASA/Canada Cooperative Communications Technology Satellite to develop the technology and experience for communications in a new space frequency band (12 GHz) and to demonstrate its utility to communicate with low-cost, small terminals in remote regions.

NAVIGATION/TRAFFIC CONTROL

Navigation/Traffic Control involves NASA's programs to develop space communications and systems which will assist in alleviating the traffic management problems of civil aircraft and US ship fleets, and in developing space-aided terrestrial position location techniques applicable to vehicles in distress. NASA is using the Advanced Applications Flight Experiments (AAFE) supported technology developments, ATS-F&G experiments and ATS-3 and 5 spacecraft to lay the foundation for solutions to operational deficiencies or more economic solutions to current high cost traffic operations.

The Shuttle Sortie Laboratory should permit short duration tests of new navigation spacecraft technology and systems.

POTENTIAL SORTIE CONTRIBUTIONS:

Experiments for the sortie mission should be those which:

- Complement the on-going NASA Communications and Navigation Program elements noted in the previous paragraphs, by filling gaps in the experiment data return expected.
- Develop the communications and related space technology that will not otherwise be conducted by industry.
- Use man's judgement and technical capabilities in a necessary and relevant manner to improve the quality and quantity of experimental results.
- Do not duplicate experiments or technology which may be done equally well using automated spacecraft.

The Shuttle Sortie design and mission capability appear to provide a practical vehicle for meeting the above C&N experiment needs and for conducting C&N experiments that: will benefit from the presence of an experimenter in space; require close observation of structural deployments, or require major radio frequency antenna changes. The Sortie mode of operation will also reduce the time, risk and cost for conducting certain short term experiments and for developing the space technology which may lead to eventual automated system application. The heavy payload capability feature of the Sortie Laboratory facilitates comparative test evaluation between alternative subsystems, components and techniques. Finally, the shuttle payload return capability not only enables the experimenter to perform an evaluation of the space environmental effects on his experiments, but in the comfort of his ground-based laboratory.

SHUTTLE SORTIE EXPERIMENTS

There are a number of experiments in which man in a space shuttle laboratory can play a useful role in the communications and navigation disciplines. A fundamental one that appears attractive is to determine the location of radio frequency interference sources on earth and to develop identification techniques for monitoring the noise environment. Another experiment is to use the vacuum of space for the testing of high-voltage, high-current communication satellite components and subsystems. Such tests might attempt to describe corona and breakdown characteristics of the equipments parametrically. Still another activity of interest would be to have a shielded room in the laboratory to permit man to develop spacecraft system and subsystem calibration, measurement and repair techniques in a zero gravity environment. A very attractive experimental field for man in space is to assist in erecting large deployable structures such as antennas. Man can evaluate various articulation devices, observe and repair any structural deformations, and perform a variety of assembly tasks for the structures. Finally, an astronaut should prove essential in the field of laser communications and tracking experiments between the Shuttle and another satellite and/or between a ground station and satellite, and assist in shuttle navigation experiments by comparing the position location information obtained via geo-synchronous satellites with on-board navigation aids.

A detailed discussion of these experiments and others is contained in Appendix A.

SHUTTLE FOR AUTOMATED PAYLOAD MISSIONS

The large weight carrying capability of the Shuttle, its multiple payload ability, and its lower cost per pound of experiment placed into space, provides an opportunity to the communications and navigation community for increased launches to obtain needed technical data and to develop required space and communications technology. In launching unmanned C&N payloads, the Space Shuttle flight crew may be able to perform some satellite check out in low orbit, make some subsystem adjustments, and calibrate instrumentation to ensure successful operation before leaving the satellite unattended. If necessary, the satellite can be retrieved and returned to Earth for more extensive repair to avoid a complete loss. The Shuttle-plus-Tug may also provide a capability to repair in space or retrieve a malfunctioning satellite from earth orbit.

Studies should be performed on the usefulness of in-orbit repair and refurbishment for geostationary C&N satellites. The size and weight-carrying capacity of the Shuttle will offer C&N spacecraft designers the possibility to use some standard laboratory equipment in place of specially constructed, highly miniaturized components which are expensive to develop and test. This should reduce spacecraft costs and possibly reduce the time and expense of detailed ground tests. Studies of this subject are also recommended.

Descriptions of NASA's planned R&D and prototype operational flights of automated ATS, Disaster Warning and Tracking and Data Relay satellites, which are in the shuttle time period, are contained in Appendix B.

The following non-NASA C&N missions are potential shuttle payloads in the 1979-1990 time period and are summarized in Appendix C:

- Intercontinental telecommunications
- US domestic satellites
- US and international aeronautical and marine satellites providing telecommunications and navigation services to ships and aircraft
- International domestic satellites possibly from India, Japan and Canada.

SPECIAL SORTIE MISSION REQUIREMENTS

Special experiment requirements on the Sortie mission are contained within each experiment description. A summary of the more significant items is contained below:

- ⊙ Air Locks
- ⊙ Contaminant Sensors inside and outside the laboratory
- ⊙ Increased incremental primary power supply, 3-6 Kw
- ⊙ EVA
- High voltage testing in Sortie Laboratories
- 3-axis platform stabilization to about $\pm 0.1^\circ$ or better
- Stabilized, controllable sub-satellites ejected from the shuttle
- Flip-over of shuttle for part of mission
- 30-day mission
- Accurate sortie ephemeris data - better than 500 meters
- High degree inclination - 60-70 degrees
- The highest altitude orbit practical
- Experiment antennas on the orbiter

POLICIES & PROCEDURES

The introduction of the sortie mode of operation affords NASA the opportunity to consider different ways of selecting payloads. Some policy areas are listed below:

1. Non-NASA institutions (private industry and other government agencies) should be encouraged to propose experiments for sortie flights in which they would pay for the experiment hardware and the space they occupy. A policy is needed for handling experiments considered proprietary by industry and to cover what NASA expects from the industry as to the disclosure of experiment results. Whatever the procedure, NASA must continue to retain final experiment approval authority.

2. Consideration should be given to assigning a lead center for management of specific "facility" type experiments such as, a large space-based antenna or a laser telescope. This will require the lead center manager to obtain user requirements from the technical community, to design and develop the instrument to meet as many of these requirements as possible and to bring the experiment equipment to the launch pad. Data analysis will be done by investigator teams, selected in advance, who will also provide technical guidance to the lead center manager.
3. Consideration should be given to a plan to develop a backlog of C&N experiments that can ride on the Sortie when mission parameters and space become available. This would reduce the possibility of flying missions with less than full capacity.

CONCLUSIONS

1. The Space Shuttle Sortie Laboratory provides a practical vehicle for meeting certain of the planned communications and navigation discipline objectives. There are some programmatic objectives which require the long lifetime of automated spacecraft and the geosynchronous orbit.
2. The Sortie Laboratory mode is expected to reduce the time, risk and cost for conducting some communications and navigation experiments and developing the space technology leading to eventual automated system application.
3. The large weight carrying feature of the Sortie Laboratory facilitates ease of comparative test evaluation between alternative subsystems and components and an evaluation of the space environmental effects on certain experiments.
4. The most useful application of the Sortie Laboratory to communications and navigation will be by performing experiments which involve man in a necessary and relevant manner to increase the useful data output and decrease instrument complexity and cost.
5. The majority of C&N Sortie experiments desire mission durations of greater than 7 days. Early implementation of 30-day Sortie missions would be useful.

6. Experiments and systems tests which require long life and/or the geostationary orbit should not be conducted on the Sortie Laboratory.
7. For all the C&N automated payloads considered in the 1979 and later time period, the synchronous orbit is required.
8. For the Space Shuttle to be useful and practical to C&N automated missions, early availability of the Tug is required. The Tug should be capable of placing at least a 1,360 kilogram spacecraft into the geostationary orbit.

RECOMMENDATIONS

1. Implement as early as practical 30-day Sortie Laboratory missions to provide increased data return from communications and navigation experiment payloads.
2. Implement as early as practical the Tug for placing automated communications and navigation payloads into the synchronous orbit.
3. Provide early funding to initiate the definition and development of selected, long lead time, experiments desired for early Sortie Laboratory flights.
4. Initiate studies of the utility of the Shuttle for retrieval, repair and refurbishment of communications and navigation satellites at the geosynchronous orbit and the cost benefit of such activity.
5. Draft new policies and procedures for the case when industry and non-profit organizations desire to place their own funded and developed experiments onto the Sortie Laboratory. Consideration of proprietary data and payment for Sortie space should be addressed.
6. Facility type experiments (lasers, large antennas, RFI) should be considered by NASA as potential experiments for the Sortie Laboratory. NASA should afford the opportunity to "guest investigators" to utilize the experiment.
7. Examine other discipline area experiment needs for commonality of special communications subsystems (e.g., large antennas, on-board data processing) to consolidate the development of this technology for Shuttle utilization.

APPENDIX A

COMMUNICATIONS & NAVIGATION SHUTTLE LABORATORY EXPERIMENTS CANDIDATES

	Mission Duration (days)	Major Location		Pointing		Orbit	
		Lab	Exterior	Earth	Space	Incl	Alt
1. <u>Characterization Experiments</u>							
RF Signal Source Location	30	X	X	X		H	H
RFI Characterization	30	X	X	X		H	H
Multipath Measurements	7-30	X	X	X		H	H
Reentry Radio Blockout	7		X		X	—	—
2. <u>Components Experiments</u>							
Radiation Cooling of Hi-Power Transmitter	7		X		X		
Open Envelope, Hi-Power Tube	30	X	X	X			
Large Area Erectable Antennas	30		X	X	X		
Space Cooled Low-Noise RF Amplifier	7		X				
3. <u>Systems/Techniques</u>							
Millimeter Wave Communications	30		X		X		
10.6 μ Laser, Hi-Data Rate Communications	30		X	X	X		
Shuttle Reentry Navigation	7		X	X			
On-Board Data Processing	7	X		X			
Bandwidth Conservation Techniques	7	X					

H = High

EXPERIMENT TITLE: TERRESTRIAL RF SIGNAL SOURCE LOCATION AND CHARACTERIZATION

OBJECTIVE

To demonstrate the ability and desirability of being able to locate (within 5 kilometers), characterize and identify a single source of known frequency (from 100 MHz up) anywhere in the world and to determine characteristics of equipment such as spectral signatures, out-of-band signals and antenna patterns. The accomplishment of this objective will:

- demonstrate the feasibility to map the electromagnetic field intensity (EFI) environment and interference spacecraft will experience in orbit.
- demonstrate the practicality of detecting emergency locator beacons of aircraft or ships in distress via satellite.

A key element in accomplishing this objective will be the development of a large 70 meter erectable antenna having a zoom capability with a frequency range of 100 MHz to 30 GHz and a pointing accuracy of $\pm 0.1^\circ$. By "zoom capability" is meant adjusting the antenna beamwidth.

RATIONALE

RADIO FREQUENCY INTERFERENCE

The frequencies used by NASA for space telecommunications are shared with other government and commercial services. This frequency sharing has created numerous incidents of radio frequency interference (RFI) on NASA command, telemetry, tracking, communications and data collection frequencies. RFI has also been experienced by other government agencies, including DOD, DOC, and DOT.

One of the causes of interference is the use of illegal transmitters within the band in question and by emissions from transmitters in other bands. The interference depends upon the in situ antenna radiation patterns of the interfering terrestrial source. Lack of detailed information on the actual usage of known terrestrial transmitters makes it extremely difficult to predict the electromagnetic environment that will be experienced in space.

DETECTION AND LOCATION OF EMERGENCY LOCATOR BEACONS

Public Law Number 91-596 requires the installation of low power, modulated continuous wave (CW) transmitters (ELT's) on all general aviation aircraft. Transmission from these ELT's at 121.5 MHz and 243 MHz simultaneously is automatically actuated upon crash. A network currently exists for determining the location of the crash. It makes use of aircraft routinely engaged in search and rescue, FAA flight inspection aircraft, and strategic Forest Service watch-towers. Consideration is also being given to the use of the extensive FAA network of control towers and communication stations. Search can be initiated for an aircraft within a short time after it is recognized that the plane is overdue. For aircraft which file flight plans, this will be recognized rather quickly. Since all aircraft flying Instrument Flight Rules (IFR) must file flight plans, the problem with this group appears to be minimal. Aircraft in the vicinity of the crash area can tune in on 121.5 MHz or 243 MHz and the crash scene localized. Planes equipped with direction finders have effected many "saves" during the first year of ELT operations. However, the vast majority of the approximately 130,000 general aviation aircraft fly Visual Flight Rules (VFR) and are not required to file flight plans although they are encouraged to do so. Since no flight plan is on file it may take quite some time before it is recognized that a plane is overdue and a search started. Further, the approximate crash area is usually not known. Complicating the situation even further is the fact that there are cases where location is difficult, even when flight plans are filed, due to mountainous, other inhospitable terrain, and areas that are not well monitored such as Mexico, Canada, etc. For these cases, representing large numbers of aircraft, different techniques or systems are required to augment the existing monitoring network. A logical method for increasing the coverage and reliability of the existing system for the situations described are satellites. In this regard NASA has been asked by FAA, Department of Aviation of the State of New Mexico, and Aircraft Owners and Pilots Association (AOPA) whether satellites of present technology could be used to assist in:

- determining if an ELT beacon was transmitting (alarm) and
- establishing the approximate crash location (position location)

DESCRIPTION

RFI

A low-noise receiver connected to a large erectable earth-facing antenna having zoom capability receives a signal transmitted by terrestrial sources. A

calibrated spectrum analyzer is used to determine frequency, power level and spectral characteristics. The frequency range of interest is from 100 MHz to 30 GHz. Several different antennas and receiver front ends are required to cover this frequency range. The zoom antenna would be erected by the crew and the zoom feature would be operated by the crew to locate signal sources. The crew would also be used for interference signal recognition and source position location verification. An artist's concept of the experiment is given in Figure 1.

DETECTION AND LOCATION OF EMERGENCY LOCATOR BEACONS

To perform experiments in detection and location of distressed vehicles, ELT transmission at 121.5 MHz or 243 MHz will be received, translated and re-transmitted from the spacecraft to the ground stations. The ground station tracks the spacecraft, detects the ELT transmission, and for low-altitude orbiting spacecraft, determines the position of the ELT. Probability of detection and location will be determined as a function of ELT equipment parameters (power, frequency, frequency stability, etc.), ELT location antenna orientation, siting effects and number of orbits. It is also envisioned that flight tests using aircraft will be used in addition to spacecraft to evaluate siting effects as aircraft flight patterns are simpler to control and therefore more economical.

EQUIPMENT

The equipment consists of zoom antennas, antenna platform control, receiver, spectrum analyzer, and data system for analyzer and antenna platform.

The payload data which follow are preliminary and are furnished for planning purposes:

SIZE

One cubic meter is required in the Sortie Lab. Antennas will be external to the lab.

WEIGHT

About 200 Kg.

POWER

About 700 watts

FLIGHT DATE

1979

SPECIAL REQUIREMENTS

Special requirements include:

- 30-day mission desirable
- A low altitude, high inclination, orbit is desirable
- Antenna pointing to within ± 0.1 is desirable
- A large antenna (70 meters diameter)

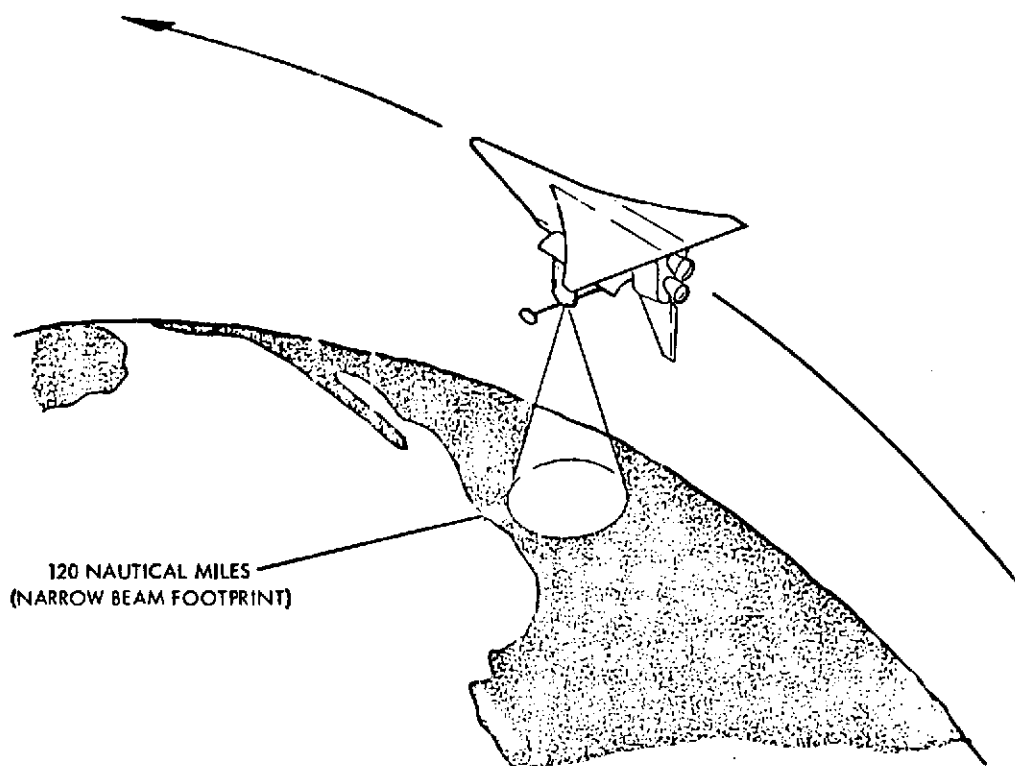


Figure A-1. Measurement of Terrestrial RF Sources of Noise and Interference

EXPERIMENT TITLE: SHUTTLE RFI ENVIRONMENT CHARACTERIZATION

OBJECTIVE

To measure the RFI environment in orbit that shuttle mission will experience, in order to minimize the detrimental effect of RFI on future shuttle missions.

RATIONALE

NASA's space telecommunication frequencies are shared with those of other services. NASA frequently experiences RFI problems in space on uplink frequencies. It is desirable to have the ability to measure these RFI fields and to be able to provide some diagnostic information which would permit the avoidance of future problems. This diagnostic capability might also provide real-time accommodations to minimize harmful effects of RFI.

DESCRIPTION

All receivers on the Sortie Lab would be designed to give an indication of the amplitude of the signals received during those times when those signals were aimed directly at the vehicle from the ground. This data would be telemetered to the ground for post-flight analysis of the electromagnetic environment. The data would also be available in the event of emergency action is required to circumvent an unexpected RFI event.

EQUIPMENT

The equipment consists of the antennas and receivers which normally are part of the Sortie Mission plus a spectrum analyzer.

The payload data which follow are preliminary and are furnished for planning purposes:

SIZE

1/2 cubic meter within the Sortie Lab

WEIGHT

100 Kg

POWER

800 watts

FLIGHT DATE

1979

SPECIAL REQUIREMENTS

None identified

EXPERIMENT TITLE: MULTIPATH MEASUREMENTS

OBJECTIVE

To measure the statistical properties of radio frequency signals simultaneously received over multiple propagation paths between Shuttle vehicles and relay satellites.

RATIONALE

Future Shuttle vehicles are likely to use geostationary communication relay satellites for voice and data transmission to ground facilities. Radio frequency signals transmitted between low earth orbiting vehicles and geosynchronous relay satellites encounter multipath transmission. A compound signal is received where different propagation delays result in partial signal cancellation and a reduced signal-to-noise ratio. This multipath fading will be most degrading when different propagation paths approach equal lengths; i.e., over horizon-to-horizon range. Four interacting effects that are important factors in this degradation are: range dependent loss, multiple cancellation loss, multiplicative noise, and intersymbol interference. A Shuttle-to-satellite experiment is required to verify the several analytic models that have been developed and to develop confidence as to which models are best suited for use in designing future space communications systems.

DESCRIPTION

In this experiment, transmitters will be located on a geosynchronous satellite and will transmit a set of sinusoidal carriers. A receiver system will be located on the Shuttle Sortie Laboratory and the received signals will be recorded and returned for post flight analysis. Orbital position and altitude data will be simultaneously recorded.

Measurements will be made at various frequency bands with special attention given to VHF, S-band, and Ku-band frequencies now being considered for use on Tracking and Data Relay Satellites, and the L-Band frequencies assigned for aeronautical, maritime and USAF use. Specific carrier frequencies being considered are: 136-138 MHz, 1535 to 1660 MHz; 2.025 to 2.3 GHz; and 13.4 to 15.35 GHz.

SORTIE REQUIREMENTS

The following preliminary payload data are based on a 7-day early (1979-80) Sortie mission, and are furnished for planning purposes.

1. Payload Element Description: This experiment is being considered for flight on the Shuttle Sortie Laboratory as one of a group of communications and navigation instruments.
2. Experiment/Sensor Content: Sortie generic equipment includes: receivers, antennas, recorders, and support electronics equipment such as oscilloscopes, signal generators, and diagnostic meters.
3. Physical Characteristics:
 - Weight - 45.4 Kg, electronics in Lab
22.7 Kg, antennas on pallet
68.1 Kg, total
 - Volume - 0.85m³, electronics in Lab
0.20m³, antennas on pallet
1.05m³, total
4. Interface Requirements: Coordination with TDRS will require continuous wave signals at proper frequencies and times.
5. Environmental Requirements: The experiment will require unobstructed R-F field of view of transmitting source. Antennas and structure must withstand thermal, 'g' levels, and vibration imposed by Shuttle.
6. Orbital Characteristics:
 - Inclination - 90° to 55°
 - Altitude - 185 to 556 Km
 - Point Accuracy - 0.5° acceptable
7. Utilities Required:
 - Power - 150 watts (maximum) 28 volts DC
 - Data - all measurement data is to be recorded onboard and returned via Shuttle

8. Crew Support: In this experiment man is required to perform system checkout, calibrate and test equipment, select desired frequency band and coordinate with transmitter source; initiate, operate and monitor recordings; observe and record meteorological conditions; and adjust equipment as required to complete measurements.

Mission Requirements

This experiment is to be conducted over a 7-30 day mission time with measurements taken during flight over various terrain and ocean areas. Additional analysis is required to determine specific measurement times and intervals in conjunction with orbit inclination and transmitter-receiver geometry. Coordination with ground surface conditions (e.g., sea state) is required.

Ground Operations Support

No special support other than normal Shuttle-Sortie Laboratory checkout and operation is required.

EXPERIMENT TITLE: REENTRY RADIO BLACKOUT

OBJECTIVE

To investigate the feasibility of communicating from vehicles entering the earth's atmosphere to a relay satellite during the radio blackout period.

RATIONALE

Attenuation of RF signals by the thermally ionized atmosphere (plasma) surrounding a reentry vehicle is of principal concern because of loss of communications during a blackout period. In the case of Shuttle this could be on the order of 0.5 hour.

Plasma sheaths surrounding space and reentry vehicles are produced by the heating of the atmosphere (to the point of ionization) and are the result of the shock wave propagating by a reentry vehicle, the exhaust of propulsion engines, outgassing of the vehicle and its components, and nuclear and solar radiation.

A frequency range of interest over which the maximum attenuation occurs is from 10 MHz to 10.8 GHz. The main approach in avoiding this problem has been to use frequencies either lower or higher than this band; e.g., X-bands, or use of materials injection (e.g., H_2O). Such techniques have not been operationally implemented, at least not on as large a scale as would be required by STADAN. Either brute force, in the form of high peak transmitter power (having limited effectiveness) or tolerance of blackout have been the mode of operation for most programs.

With the advent of communication relay satellites, it is possible to provide an indirect propagation link from a reentry vehicle to the ground.

The use of high frequencies, i.e., 1.5 to 15.35 GHz and higher, and directing an RF signal to a relay satellite may provide a technique for overcoming such communications blackout for future space operations.

DESCRIPTION

This experiment consists of monitoring the communications signals from the Shuttle vehicle entering the earth's atmosphere. Because the general features of the frequency response of reentry plasmas are known, it is possible to place some bounds on the choice of frequencies to be used.

To conduct this experiment, tracking antennas and receivers in a geostationary relay satellite, such as a Tracking and Data Relay Satellite (TDRS), must be configured corresponding to the chosen set of transmitters in the shuttle reentry vehicle. Within the shuttle, certain quantities must also be measured and recorded for post reentry readout. Principal among these are the VSWR at the transmitting antenna during the reentry, vehicle attitude, and altitude history. It might be useful for the shuttle to be furnished with a mass spectrometer to obtain an in situ measurement of outgassing species that would contribute to the ionization. Vehicle altitude, as well as velocity profile and meteorological conditions, can be obtained from simultaneous ground observations. The general configuration for these experiments consists of relatively broadbeam (about 10°) antennas on the shuttle, and narrower beam (2° to 5°) tracking antennas on the TDRS.

Signal-strength measurements received at the TDRS should be made independently for two orthogonally, linearly polarized signals. Depending upon the data received, additional instrumentation beyond the monitoring of the received signal strength should be considered for later experiments to obtain:

- Frequency response of reentry plasma as a function of reentry angle
- Angle of arrival changes received at TDRS due to diffraction of radiation by finite reentry plasma boundaries.
- Effect of dispersion (frequency dependence of phase velocity) on data rate. This can be caused by either the dispersion indicated in the second item above or the (probably smaller) dependence of plasma refractive index on frequency, and possibly on the value of magnetic field.

These experiments would require more complex instrumentation in both the shuttle and the TDRS. The general requirements would be for transmission of sets of both analog and digital data streams from the shuttle, and comparison to replicas at the ground.

EQUIPMENT

The following payload data are preliminary and are furnished for planning purposes:

SPECIAL REQUIREMENTS

The experiment described has real-time telemetry data requirements. A TDRS will be required and autotrack receiving antennas might be called for when

frequencies of X-band and higher are employed. For most reentry geometries it is likely that broadbeam antennas on both the shuttle and TDRS could be used. Knowledge of shuttle ephemeris is important in this experiment since the reentry trajectory must satisfy viewing from TDRS and a well-instrumented ground station.

Crew participation and support would include appropriate equipment connection, initial antenna pointing and monitoring.

The blackout experiment would be more useful if, coincidentally, the effects of using physical and chemical means of modifying reentry plasmas were evaluated. Although not directly a portion of the considerations here, the problem of designing antennas that can survive the range of alternative reentry conditions is an important one.

An alternate to using the shuttle as a reentry probe would be to employ a sub-satellite launched from the shuttle. This approach would allow a Shuttle-Sortie Laboratory in lieu of TDRS, would eliminate the need for real time data relay to ground stations, and would provide a flexible technique for conducting blackout investigations.

EXPERIMENT TITLE: RADIATION COOLED RF POWER AMPLIFIER COLLECTOR

OBJECTIVE

To establish the operational feasibility of using direct radiation cooled collectors for multikilowatt RF power amplifier tubes in satellites.

RATIONALE

Multikilowatt amplifiers are needed for real time television from deep space and for wideband communications (data, television, or multichannel voice) from earth synchronous orbit to low cost receivers. A significant design problem associated with the operation of high power RF amplifiers on spacecraft is the rejection of heat from the electron beam collector. A potential solution is to operate the collector at high temperatures and radiate the heat directly to space. Radiation cooled collectors have been successfully operated in an earth-based laboratory, but have required the use of a sapphire window in the vacuum jacket.

DESCRIPTION

The experiment would be performed in conjunction with experimental operation of a tube with open vacuum envelope. This experiment would be placed on an extendible boom within an airlock. Operation of the tube would be with full boom extension to give unobstructed radiation to space. After opening the tube (Figure A-2) outside of the sortie lab, the operating characteristics of the tube would be measured including the temperature distribution in the collector and associated tube structure. After operation, the tube may be brought back into the sortie lab (with collector cover on) and the boom and airlock used for other experiments.

EQUIPMENT

The hardware required includes high voltage power supplies, voltage and current meters, an RF power source, RF power meters, thermocouples, and a data recorder.

SIZE

The volume required is estimated to be 2 cubic meters.

WEIGHT

The weight requirement is estimated to be 40 Kg.

POWER

The power requirement is a 4 Kw, dc bus with a 10 hour duration.

FLIGHT DATE

One flight between 1979 and 1981 is proposed.

SPECIAL REQUIREMENTS

- Air lock with platform extendable to orbiter envelope
- Seven day operation adequate
- One operator to manipulate instrumentation
- No gases which could cause electrical breakdown between collector plates are permitted in the vicinity of the tube. A Faraday shield may be used to protect the experiment from electromagnetic fields.

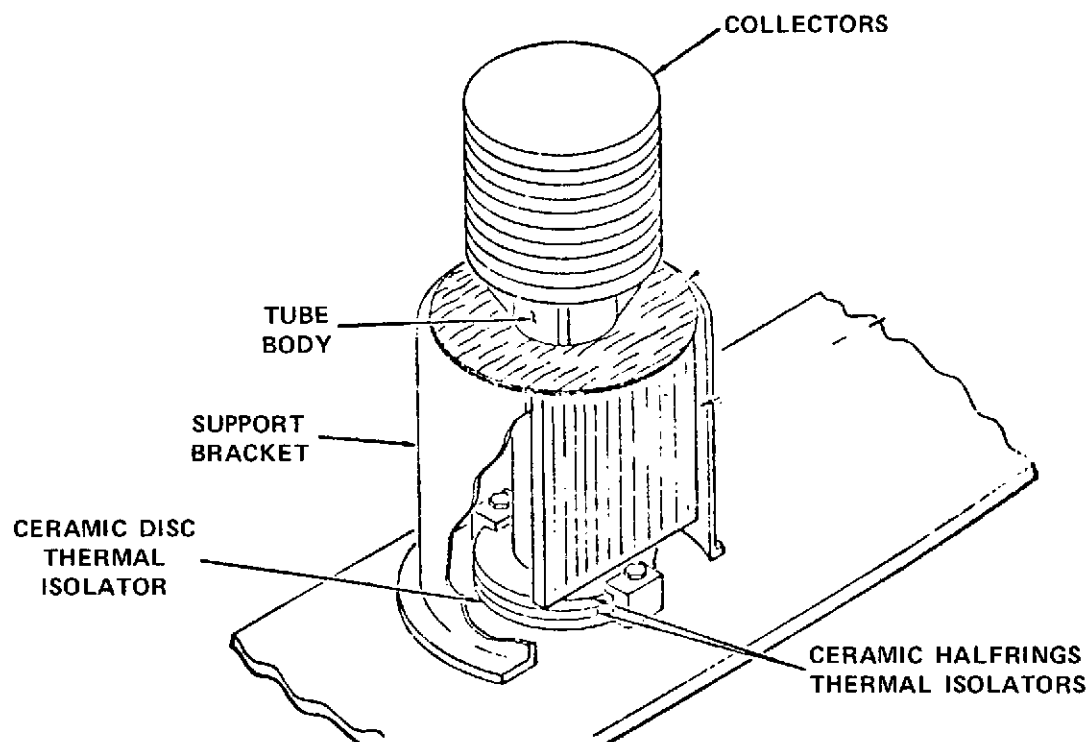


Figure A-2. Transmitter Tube with Multiple Depressed Collector
with Collector Cover Removed

EXPERIMENT TITLE: OPERATION OF OPEN, HIGH POWER, RF AMPLIFIER IN SPACE

OBJECTIVE

To determine the feasibility of operating high power RF amplifier tubes which are open to the space environment in the vicinity of a spacecraft located outside of the earth's atmosphere.

RATIONALE

Some communication applications, such as satellite broadcasting, will require long life operation of multi-kilowatt, (11.7 to 12.5 GHz) RF power amplifiers in earth satellites. The life of these tubes is shortened by contamination from internal outgassing. The opening of the vacuum envelope to space may be a feasible, low-cost method of pumping such tubes thereby prolonging the life. On the other hand, material in the vicinity of the spacecraft may contaminate and destroy the tube cathode.

DESCRIPTION

The experiment would consist of measuring the performance of several tubes before and after opening the vacuum envelopes and then resealing and returning the tubes to an earth laboratory. One technique suitable for unsealing and resealing the vacuum envelope in space is to use a meltable gasket of indium. Tube operating heat would be sufficient to melt the indium before separation of the collector cover. Removal of tube power would reseal the tube after the cover is replaced. After return to earth the internal content of some tubes would be analysed while others would be life tested and compared with tubes that were not opened to space.

The in orbit procedure would be to place one tube at a time on an extendable platform, operate the tube, and then return the tube to the Sortie lab. About 2-4 man-hours would be required to change tubes on the experiment platform within the airlock. Different tubes might be operated at different distances from the spacecraft to give different exposure levels to contaminants.

Gases which would cause immediate electrical breakdown between the collector plates are not permitted in the vicinity of the tube. Exterior electromagnetic fields which would affect contaminant deposition rates are not allowed.

EQUIPMENT

The hardware required includes high voltage power supplies, voltage and current meters, RF power source, RF power meters, spectrum analyzer, gas analyzer, and data recorder.

SIZE

2 cubic meters is estimated as the required volume.

WEIGHT

80 kg is the estimated weight requirement.

POWER

A 4 kW, dc bus, with virtually continuous operating capability is required. Proposed flight date: 2 flights (minimum) between 1979 and 1981 is proposed.

SPECIAL REQUIREMENTS

- Air lock with platform extendable to orbiter envelope
- Gaseous, ionic and particulate contamination instrumentation
- Up to 30 day operation
- One operator to open vacuum seal and manipulate instrumentation

EXPERIMENT TITLE: ERECTION AND PERFORMANCE OF ANTENNAS AND ASSOCIATED EQUIPMENT

OBJECTIVES

The objectives of this category of experiments include:

- The evaluation of general techniques and shuttle facilities for erecting in space large antennas and associated equipment, and including the test of specific erection and equipment embodiments.
- The measurement of the static and dynamic mechanical properties of antennas and associated equipment and their electrical performances in a zero-gravity space environment.

RATIONALE

There are many potential applications of space antennas that require or would benefit from the following antenna related properties: large transmitting antenna gain or radiated power; large receiving apertures; specially shaped coverage; high degrees of controlled directivity, isolation or discrimination; use of two independent polarizations and multiple independent patterns in a frequency band; and more efficient spectrum usage. The applications that may especially benefit from one or more of these space antenna properties may be supported by public, private, government or commercial operations both domestic and foreign or international. Typical applications that would benefit most highly from these space antenna properties include:

- Communications with small terminals, especially mobile, remote or emergency operations where alternative landline or other satisfactory communications are not available.
- Broadcast to small terminals, especially mobile or remote terminals with no satisfactory alternative.
- Traffic management (airborne, maritime and land).
- Tracking and data relay satellites working with small terminals.
- Earth and Ocean Physics measurements programs (radiometers, altimeters, etc.).

- Deep Space Tracking and Data network terminals when especially large apertures and continuous radio frequency contact are important.
- Radio Astronomy when especially large apertures are needed or if large working solid angle with small atmospheric or ionospheric influence is important.
- Solar energy capture and retransmission to earth.

In most of the potential applications of earth directed space antennas, the larger apertures and needs for space erection increase with decreasing frequency. Also the earth terminals tend to be less burdensome, particularly in mobile applications, the lower the frequency down to the low UHF. Thus, the greatest need for experiments with the erection of large antennas for these applications is likely to involve the UHF and perhaps emphasize the lower portions of the UHF. Applications involving higher frequencies, e.g., above 10 GHz, are less likely to require the space erection of individual antennas, but they may involve the erection of families of independent antennas in conjunction with large solar cell arrays. Also, the Sortie environment may prove to be attractive for measuring the performance of the antennas in space as distinct from erection behavior.

DESCRIPTION

This category of experiments may include either or both of the following:

- Tests of deployment performance of space antennas and associated equipment after a shuttle launch and in the zero-gravity space environment. This may involve automatic erection systems, remote maneuvering unit operation, or man observed and controlled operations in space.
- Tests of mechanical and electrical performance of space antennas and equipment. This may include the measurement of mechanical tolerances and behavior as a function of control and temperature dynamics and mechanical linkage to associated equipment such as large flexible solar cell arrays, and it may involve the measurement of electrical performance in terms of antenna patterns, isolation and discrimination achievable in direction and polarization, and the stability and control behavior of the various performances.

Since a variety of applications, configurations, and performances may be involved, a large range of experimental parameters and activities may be proposed. Reflectors, horns, arrays, lenses, and other types of antennas may be

considered. The erectable antennas may have deployed dimensions from 5 to 100 m or more. They may be unfolded, unrolled, inflated, extended, or assembled from separately launched components. They may vary in size from absorbing only a small fraction of one shuttle volume and payload to the use of several shuttles to fabricate one space antenna. Experiments for most earth oriented applications are likely to involve antennas less than 100 meters in maximum dimension, and requiring only a fraction of one shuttle volume and payload. The space oriented applications (radio astronomy, deep space tracking, etc.) are more likely to consider the larger antennas that might provide greater performance than could be achieved on earth for a given cost.

Reflectors, horns and other large antennas that require precise mechanical tolerances will need large measurements efforts to determine the mechanical performances in space, whereas arrays or antennas that can be tuned, adapted, and controlled electrically may not need elaborate measurements of the mechanical performances.

Experiments for earth oriented applications that involve space erected antennas are likely to have greatest urgency, and some of these experiments should be ready for early shuttle flights. Other experiments, particularly large space oriented antennas, may not make shuttle demands until the early 1980's.

The following are a few illustrations of the types of experiments that may become of interest: Multiple shaped beam antennas to provide greater independent frequency reuse and spectrum capability for communications or broadcast might be provided using lenses or reflectors with multiple feeds or using arrays with multiple interconnection networks. Arrays can be controlled better electrically to compensate for mechanical distortions so as to provide the desired shaped patterns and greater independence between patterns than seems possible for multiple feed reflectors or lenses. However, the networking and control costs for arrays are greater so as to make them most attractive for small numbers of simultaneous independent beam patterns while lens may become more attractive in providing large numbers of independent beam patterns.

SORTIE REQUIREMENTS

The Sortie requirements will vary greatly with the particular experiment. Figure A-3 is one example of a large aperture deployment. The Shuttle's large payload and volume availability could be used to supply additional needs for stability, power, etc., within the experiment payload. Many of the experiments that evaluate antenna erection would be relatively insensitive to orbit

specifications. The crew support and data link requirements are likely to be interdependent. It would be desirable to have data links through synchronous relays that would permit continuous remotely manned operation from earth of the experiments in any shuttle orbit. This may mean a capacity for the equivalent of several simultaneous high quality TV channels.

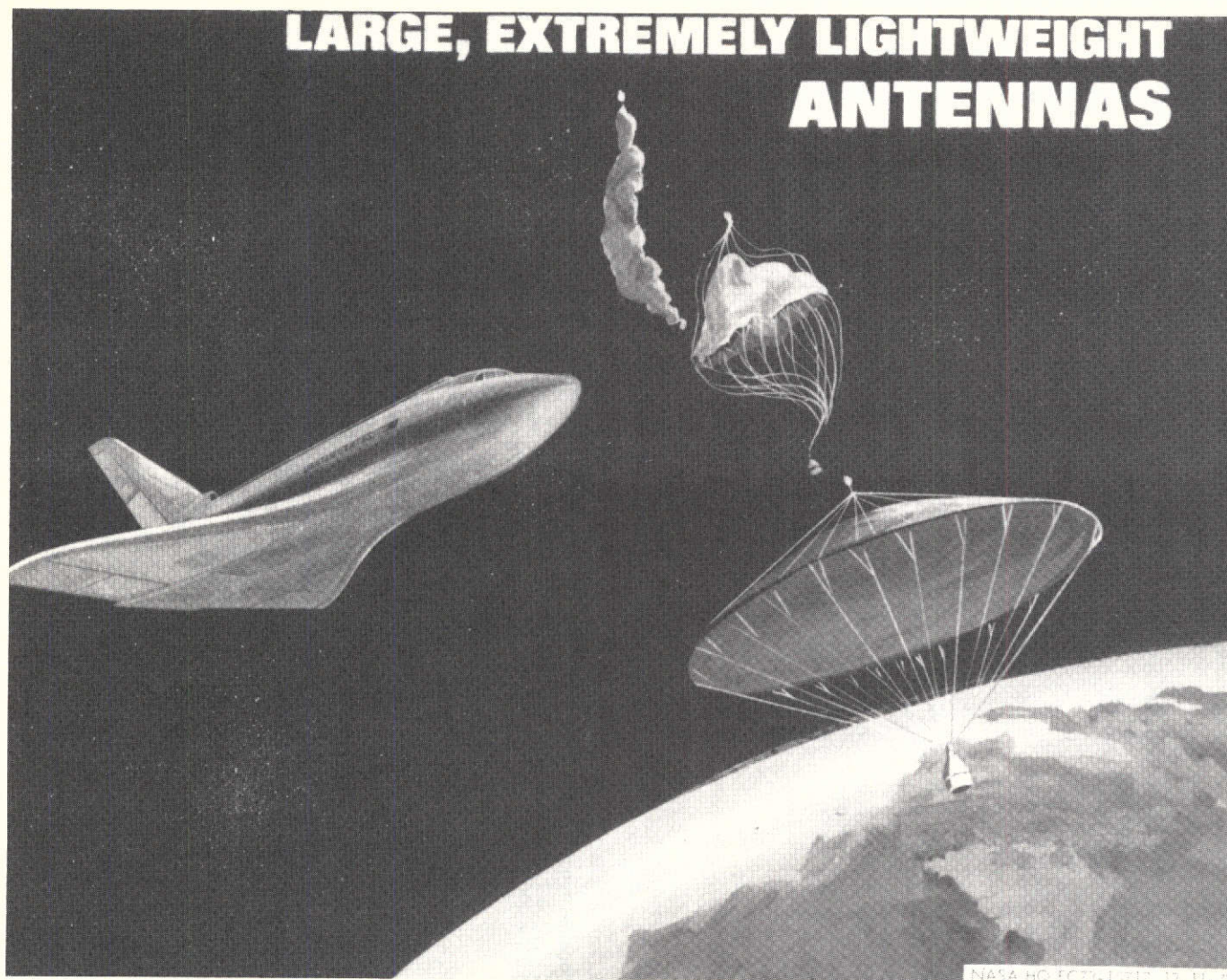


Figure A-3. Large, Extremely Lightweight Antenna

EXPERIMENT TITLE: SPACE COOLED LOW NOISE RF AMPLIFIER

OBJECTIVE

To demonstrate the possibility of radiation cooling a low noise RF amplifier for a spacecraft radio receiver.

RATIONALE

The efficiency of repeater type communication satellites is partially dependent on the noise figure of the satellite receiver. FET's are understood to be available with low noise characteristics when cooled to low temperatures. By this means up to 2 dB signal to noise ratio improvement could be achieved for typical C-band communication satellite receivers.

DESCRIPTION

After suitable ground development and testing, an amplifier would be exposed from the Sortie so that it would be cooled by direct radiation to space. The operating characteristics would be measured with special attention to measurement of the noise temperature. This would be measured when the amplifier is connected alternately to an antenna and a calibrated radio noise source.

EQUIPMENT

In addition to the amplifier, equipment needed includes: RF signal source, noise temperature receiver, modest antenna, calibrated noise source, associated microwave transmission circuits, and data recorder.

SIZE

1 cubic meter is required within Sortie lab, a C-band receive antenna and a 5000 cubic meter receiver is required outside the lab.

WEIGHT

30 Kg is the estimated weight requirement.

POWER

500 Watts of power should be required.

FLIGHT DATE

One flight in 1980 or 1981 is proposed.

SPECIAL REQUIREMENTS

- The receiver would be mounted external to the Sortie lab.
- Receiver input, output, and instrumentation would be accessible from inside the Sortie lab.
- No electromagnetic radiation within the passband of the receiver would be allowed on the Sortie.
- Receive antenna is to be earth facing, $\pm 2^\circ$.

EXPERIMENT TITLE: MILLIMETER (MM) WAVELENGTH COMMUNICATION LINKS

OBJECTIVE

To evaluate and demonstrate, by actual tests between the Sortie lab, shuttle subsatellites and/or other appropriate spacecraft, the communication potential of the millimeter wave bands (27.5-31 GHz and 54-190 GHz) for space/space communication links with particular emphasis on the antenna directivity problems associated with operation in these bands.

RATIONALE

To meet the ever increasing demand for information transfer, it is essential to exploit higher and higher frequency bands which provide the additional bandwidth required by high data rate communications and enable the development of higher gains in the limited antenna dimensions that can be accommodated on most spacecraft. In the last decade the 1-10 GHz band has been extensively exploited for operational communication systems, and the 12-14 GHz band is planned to be intensively investigated during the 1970-80 period. The above millimeter bands have been allocated for space utilization at the 1971 WARC, and their potential needs to be developed. Millimeter wave propagation test data from ATS-F & G missions will provide essential baseline data for detailed Sortie experiment design.

The development of millimeter wave technology will be applicable to international wide-band communications involving satellite-to-satellite relay links. It is envisioned that international communications in the next two decades will encompass video and other wide-band information transmissions between:

- Heads of national governments
- United Nations and member governments
- International business concerns
- News networks
- Military alliance organizations (such as NATO)

Additionally, millimeter wave technology will be applicable to wide-band communications needed for orbital data links in lunar and planetary exploration programs.

An important aspect of the tests will include the use of retrodirective arrays as a means of achieving high directive transmission gain without incurring the severe installation constraints and stabilization control problems that apply to use of single large antenna units on board spacecraft. A retrodirective array automates its transmission directional beam control by utilizing the carrier signal energy received from a communicating station to pilot its beam by adaptive phasing, in the direction of mutual beam acquisition and lock-on. The Shuttle Sortie will enable the testing of millimeter wave antennas and arrays mounted on stable platforms without the critical concern for airfoil streamlines, structural integrity, and flight dynamics, that would constrain such tests on airplanes; and without the problems associated with such experiments on automated satellites.

DESCRIPTION

In common with optical communication links between moving spacecraft, a major problem concerns the development of signal acquisition techniques and frequency and spatial tracking systems to establish and maintain the link. Also, it is necessary to determine the effect of spacecraft thruster exhaust products on signal absorption, and the effects of electron density on wide-band phase coherence.

Prime test modes for space/space link evaluation include:

- Subsatellite transmission to the Sortie lab,
- Two-way transmission, Sortie lab to subsatellite to Sortie lab,
- Transmissions from other spacecraft to the Sortie lab.

PAYLOAD ELEMENT

The millimeter wave space/space link tests require an attitude-controllable (from Sortie lab) subsatellite whose orbit with respect to Sortie is not presently defined. It is highly desirable to conduct MM wave experiments concurrently with laser link tests thereby utilizing a common subsatellite and attitude stabilization platform on a 30-day mission. There will be a need for controlled Sortie thruster firings for plume attenuation measurements; MM wave transmission through the plumes will be required. It is anticipated that some degree of equipment commonality will exist between this experiment and experiments designed to investigate communication through re-entry generated plasmas to ground terminals.

Since the longer wavelength of MM communications will be less critical than optical wavelengths, the more stringent specification requirements of the stabilized attitude tracking platform for the Laser Data Relay Link Experiment will apply. For diversification of tests on different missions, directional coverage is desired off one end of the Sortie lab, as well as out from the cylindrical shell of the Sortie. This will permit modes of test which change rapidly in direction as compared with range, as well as modes wherein rapid changes of Doppler phasing occur relative to spatial directional changes.

EQUIPMENT

ANTENNAS AND ARRAYS

A variety of antenna and array configurations will be investigated, varying from quasi-optical reflector elements to wave-guide slot arrays. These will be mounted on the attitude stabilized platform. Supporting instrumentation within the Sortie will be mounted in a maximum of two standard electronic racks weighing about 150 lbs. in a cubical area approximately 5' x 5' x 6'.

The platform-mounted, low-band transmitter/receiver package can be modified from that developed for the ATS-5 and later series spacecraft. Trial single antennas are not expected to exceed a weight of 10 lbs. each. Antenna arrays are less certain because of new technologies for shifting phase. However, a weight reservation of 100 lbs. is believed reasonable. A specific high-band design has not been established but is expected to be physically comparable in size, or smaller, than the lower band equipment. For the initial series of tests, it is expected that only the low-band equipment need be accommodated because of difference in development time that will be required for the two bands.

SENSOR CONTENT

Besides the antennas and arrays in a variety of configurations to be tested, the instrumentation for the Sortie lab will include:

- High stability tracking platform and antenna mount.
- Millimeter wave transmitters and receiver, provided with several basic frequency options in the specified bands, to be determined by the experimenter, plus fine tuning.
- Pseudo-random code generators.

- Bit error comparators.
- Power meter.
- Wide-band modulators.
- Waveguide patching panel.
- Digital tape recorder and minicomputer.
- Spectrum analyzer.
- Digital counter.
- Clock signal timing source.
- Wide-band oscilloscope.

SPECIAL REQUIREMENTS

Interface

All experiment equipment (other than subsatellite components) will be mounted in the Sortie lab. Because of the temperature dependence of antenna elements at MM wavelengths, it is highly desirable that the stable platform be in a shirt-sleeve or temperature controlled environment with the RF radiations through an RF transparent window. Checkout support, control, and display units will be self-contained in the experiment racks.

Environmental

Moisture condensation on the RF transparent window cannot be tolerated. Temperature limits and "g" levels during test periods will be stringent and allowable values will have to be determined. It is not expected that electromagnetic interference will be a significant constraint at these frequencies.

Orbital Characteristics

There are no Sortie special requirements for Sortie orbit attitude or inclination. Thirty-day missions are more desirable than those of shorter duration to permit maneuvering between subsatellite and Sortie trajectories. Pointing accuracy and duration, pointing frequency, and stability levels and duration requirements

derived for millimeter wave experiments, designed for automated spacecraft such as ATS-5, serve as a basis for determining their applicability to Shuttle missions.

Utilities

Total power required during experiment operation, exclusive of stable platform and temperature control requirements, is approximately 2KW. To permit maximum utilization of commercial components, 60 cycle power at 115 volts nominal, is preferred.

Experiment data is planned to be recorded on magnetic tape units supplied as part of the experiment, and no significant amount of on-board data processing is anticipated. Processing of the experiment data is planned upon termination of the Sortie.

Voice communication for consulting with earth-based co-workers is essential.

Crew Support

The experiment is planned to be directed and operated by a MM wave communications specialist who will make all operational adjustments, record all pertinent data, and coordinate all experiment activities and maneuvering requirements with the Shuttle Commander. It is expected that various test phases can be divided into four hour segments compatible with other experiments in the Sortie and available view periods with other spacecraft.

Mission

Typical test runs for different installed antenna configurations are expected to involve 8 to 10 days of accumulated test time during a 30-day mission. Two different concepts of testing will be conducted. In one, acquisition of subsatellite beams will be tested as the Sortie cuts through the major and minor beam lobes. In the other concept, the mode-locked Sortie millimeter communication link would recede from a subsatellite in the approximate direction of a radiated beam. Observations would then be made of the signal acquisition and frequency tracking problem as the Sortie range changes and the subsatellite moves in and out of the principal beam lobe.

The general millimeter wave technology is such as to allow consideration of tests in conjunction with synchronous and low-altitude satellites that will be in orbit in the period of 1979-1985. The lower frequency band (27-31 GHz) will be available for flight experiment in 1979 or 1980; the higher frequency bands

(54-190 GHz) will be ready for test in about the 1983-1985 period. A minimum of three Sortie flights (also proposed for laser communications evaluation tests) are proposed for initial millimeter wave tests.

Ground Operations Support

It is assumed that MM wave antenna pointing directional information to subsatellites (or other spacecraft) and relative radial velocity information will be relayed from ground tracking facilities to the Sortie lab experiment specialist to assist him in the space pointing and frequency acquisition problem. It may prove desirable to provide a lower frequency beacon in the subsatellite to assist in the initial acquisition problem.

No special prelaunch checkout, storage, or environmental constraints are foreseen at present.

EXPERIMENT TITLE: 10.6- μ m LASER DATA RELAY LINK (LDRL)

OBJECTIVE

To develop and test a system to provide 400-MBps communication capability between a low-altitude satellite and a synchronous satellite with a spacecraft terminal weight of 60 lbs and a prime power requirement of 125 watts.

RATIONALE

In 1979 or later it is likely that a synchronous satellite will be active which carries a 10.6- μ m Doppler-tracking, laser heterodyne receiver. This receiver will be extensively exercised from a ground station which will simulate a low-altitude satellite performing a data-relay operation. A space shuttle experiment will provide a relatively low-cost test of the LDRL under actual space-to-space conditions. The development of this capability will meet NASA's requirements to service high data-rate earth observational spacecraft for the next decade beyond 1980.

DESCRIPTION

The synchronous satellite receiver is not discussed here. The Laser Transmitter on the Space Shuttle:

- Wavelength — 10.6 μ m (28,000 GHz)
- Prime Power — 125 W
- Carrier Power — 1 W
- Modulation Mode — Double Sideband Suppressed Carrier
- Modulation Format — Digital, Non-Return-to-Zero (NRZ)
- Modulator Bandwidth — 220 MHz
- Antenna Gain — 92 dB
- Antenna Diameter — 5 in. (12.5 cm)

- Antenna Coverage — Hemisphere
- Weight — 60 lbs.
- Size — 2 cu. ft.
- Operator — Deploy and direct system during acquisition
- Stabilization — $\pm 0.1^\circ$ or better

SPECIAL REQUIREMENTS

- Telescope must be deployed outside Sortie.
- Synchronous satellite terminal must be available.
- As noted above $\pm 0.1^\circ$ stabilization is required to reduce acquisition time. A two-week mission is adequate for proof testing after extensive synchronous satellite to ground tests although a 30-day mission is desirable.

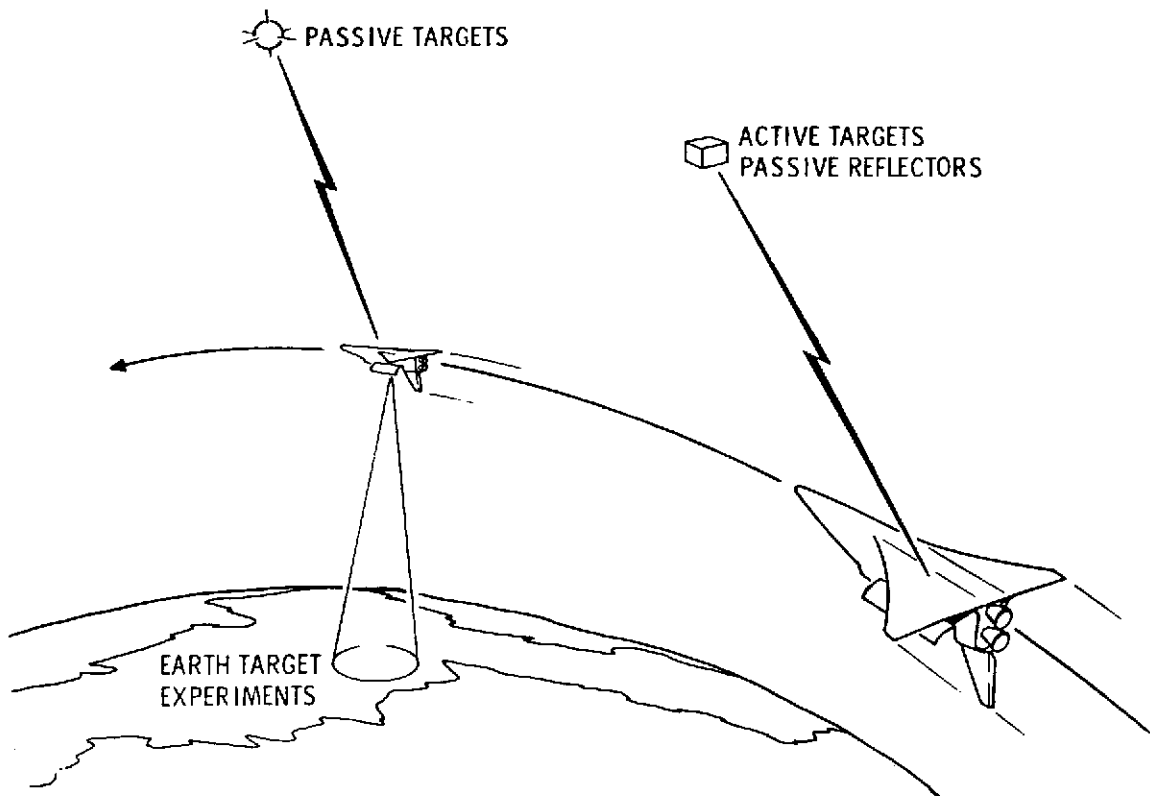


Figure A-4. On Board Laser Ranging & Communications

EXPERIMENT TITLE: SPACE REFERENCED TRAFFIC MANAGEMENT SYSTEM

OBJECTIVE

To assess the ability of Pseudo-random noise (PN) satellite ranging systems to position fix and provide digital data for the shuttle from take-off to orbit and back to landing.

RATIONALE

As the Shuttle is the cargo vessel of the Space Age, so too is a constellation of satellites the Navigation Aid of the Space Age. Numerous studies have shown that the utilization of space-referenced platforms for combined communications and navigation is a viable concept. The absolute utility of a satellite system needs to be demonstrated with live experiments in the various application environments. Recent studies for the DOT, NASA, and the DOD and the Maritime Administration have indicated that a PN code system such as proposed in this experiment may be the optimum for conducting Traffic Management functions.

Satellites in current planning that should be available for this experiment include the NASA ATS series, and the Defense Navigation Satellite System (DNSS).

The benefits of this Shuttle experiment to NASA are:

- A demonstration of these techniques for orbit to orbit maneuvers for later space mission applications.
- A demonstration of the use as a collision avoidance system between commercial aircraft and spacecraft to benefit future space travel.
- To provide a continuous digital data link for information transfer.
- To demonstrate the handover from space referenced coordinate system to a localized system during landing and takeoff and determine whether handover is necessary. Future applications might lead to landings in remote areas that are completely uninstrumented.
- To provide a navigation system with high resolution for Shuttle operations in all environments.
- The system could serve as a back-up operational navigation system.

DESCRIPTION

One or, preferably, several geostationary satellites will be utilized to feed through an L-band PN coded signal from a ground based source to the shuttle. A navigation receiver-processor located on the shuttle will be utilized to provide position and velocity data that can be compared with other position fixing data (i.e., laser trackers in the orbit phase and actual survey data and other ground based trackers during the landing and take-off phases of flight) to determine the capabilities of this system in various geometrical formations.

EQUIPMENT

The payload element is considered small and could be carried with any or all mission complements now being planned.

The Experiment Sensor contains: a Navigation Receiver, a Mini-computer, a Display and Control Unit, an Antenna and Power Interface, and a Recorder.

SIZE

All equipment should fit in standard 19 inch relay racks with a total volume less than 2.5 cubic meters.

WEIGHT

The total weight will be less than 200 pounds.

POWER

150 Watts of 115 volt AC power will be required during experiments.

SPECIAL REQUIREMENTS

Discussions with antenna specialist of JSC have confirmed that three (3) appropriate L-band antennas are planned to be on board. Modifications to support this experiment will consist of, at most, internal switching circuitry to gain access to these antennas.

Interface

Access to L-Band Antennas on main body of shuttle is required as well as access to shuttle timing system.

Environmental

No problems anticipated.

Orbital Characteristics

No special requirements.

Data

Digital, 2 kilobits, 2 hours, max. per operation up to 3 operations a day, 25% real time transmission is anticipated.

Mission

A minimum of one Shuttle mission will be required.

Ground Operation Support

A landing site instrumentation operation and ground computer support will be required.

Crew Support

Men might be utilized to view the display unit and compare with other shuttle navigation systems to provide inputs on the operational quality of the data.

EXPERIMENT TITLE: ON-BOARD DATA PROCESSING

OBJECTIVE

To demonstrate the characteristics of several data compression algorithms using real data sources and real satellite links.

RATIONALE

Several disciplines such as astronomy and earth resources indicate a potential need for transmission of large quantities of data from 1 to 100 Mbps. Because of RF bandwidth constraints, it is desirable to demonstrate to users the characteristics of various data compression algorithms. The experiment would make comparative measurements using real data and would use the ability of man to change algorithms and make equipment adjustments as the experiment proceeds.

Communication links incorporating data compression would enhance the data transfer from scanning types of sensors such as multi-spectral scanners, automated telescopes, and television sensors. Such links will be needed by NASA, Department of Agriculture, Department of Defense, Department of Interior, Department of Commerce and Department of Transportation. The data will be used for diverse applications such as surveying natural resources, weather prediction, flood prediction and control, astronomical research, pollution detection, mapping, agricultural disease and pest control, and shipping route selection.

DESCRIPTION

The experiment would consist of using data from representative sensors such as a multi-spectral scanner and process the data to remove redundancy and code it for radio transmission. The coding equipment would be either programmable or modular so that a variety of algorithms and coding techniques could be demonstrated. In addition, provision would be made to adjust parameters such as decision thresholds or word lengths as the experiment progresses. The equipment would consist of a representative instrument, digital processing equipment, data recording equipment, and data transmission equipment.

EQUIPMENT

This experiment is best flown in conjunction with other experiments such as Earth resources survey or an astronomical telescope to provide a comparative data base.

Primary instrumentation would be a small computer and peripheral equipment to:

- interface with the cooperating sensor and the telemetry system
- control the experiment.

SIZE

A volume of 5 cubic meters will be required.

WEIGHT

The experimental package will weigh 400 Kg.

POWER

115 volt, 60 Hz, AC power will be required as follows:

- 2 Kw average during active phase
- 2 Kw peak during active phase

FLIGHT DATE

A flight date of 1980 is proposed.

SPECIAL REQUIREMENTS

Interface

Location—Sortie Lab

Storage—Magnetic or film type supplies

Support Equipment—Oscilloscope, multimeters

Controls and Displays—Standard rack mounted keyboard tape cassette, line printer

Configuration—Standardized equipment locks

Environmental

Cleanliness—Terrestrial laboratory equivalent

Temperature Constraints—0° C to 50° C

Vibration & Shock Limits—1 g, 3 to 10 Hz, 4 g, 11 ms

EMI—Commercial computer equipment

Orbital Characteristics

No requirements—determined by cooperating imaging experiments.

Utilities

Data—

- Form—Digital electrical and tape or film
- Rate—1 to 100 Mbps
- Duration—15 minutes
- Operations per day—2
- Percent real time transmission—none

Communications—

- Dump mode
- Rate—0.5 to 50 Mbps
- Voice—Standard links for coordination

Computer support—none

Data processing—none

Other utilities—none

Crew Support

Number and skills—1 test engineer

Functions—operate equipment, analyze operation

Duty cycle—one shift per day max.

Mission

Flight Frequency—4 per year

Flights Required—4 to 8

Mission Duration—3 to 5 days

Deployment and Retrieval—none

Resupply/revisits—none

Ground Operations Support

Prelaunch checkout—approximately 1 hour coincident with cooperating sensor checkout

Prelaunch constraints—none

Pad access—same as general Sortie lab

Special cleanliness—none

Special storage and environmental control—same as internal to Sortie lab

EXPERIMENT TITLE: BANDWIDTH CONSERVING MODULATION/DEMODULATION

OBJECTIVES

Establish and measure the characteristics of experimental communication links using high data rate digital transmission techniques that conserve RF bandwidth.

RATIONALE

The needs for high data rate digital communications for information networks will place increasing demands on precious radio frequency allocations. Modulation/demodulation techniques such as multiple phase and amplitude shift keying and multiple amplitude shift keying have the potential for achieving coding gains in signaling efficiency at only modest cost in RF bandwidth utilization. They are thus applicable to satellite information network designs. The purpose of the experiment is to make comparative performance measurements on real links after suitable theoretical development and laboratory simulations have been performed.

Information networks are being developed or considered for various civil users under the auspices of Department of Health, Education and Welfare; Department of Justice; and NASA. These information networks will be used for exchange of medical information, educational information, criminal data, business data, and perhaps mail.

DESCRIPTION

The experiment would consist of establishing data links between ground stations via transponders in the Sortie Laboratory. Test data would be transmitted for the purpose of measuring error characteristics. The links would use various modulation forms including uncoded phase shift keying, multiple phase shift keying, multiple amplitude shift keying and multiple phase and amplitude shift keying. The transponder would be implemented from modular laboratory type equipment that could be readily configured and adjusted by an astronaut for each modulation/detection technique. The equipment would include a modular transmitter-receiver, noise temperature monitor, signal generators, antennas, spectrum analyzer, modulators and demodulators.

EQUIPMENT

PAYLOAD ELEMENTS

The instrumentation would consist of 4 elements, a steerable antenna, transmitter-receiver, modulator-demodulator, and test instruments. These would not require the full Sortie lab capability and could share flights with other missions.

EXPERIMENT/SENSOR CONTENT

None in addition to the payload element.

SIZE

- 4 m³ internal to Sortie lab
- 1 m dia steerable parabolic antenna on pallet

WEIGHT

- 300 kg

POWER

- 115V 60 Hz AC
- Average power — 2 kw
- Peak power — same as average

FLIGHT DATE

A flight date of 1980 is proposed.

SPECIAL REQUIREMENTS

Interface

Location—Standard racks internal to Sortie lab. Steerable antenna mounted on pallet.

Storage—Magnetic tape supplies — 10 reels

Support equipment—none

Checkout support—none

Controls and displays—Rack mounted standard oscilloscope, line printer, and meter displays, keyboard input.

Configuration—Transmitter-receiver, modulator-demodulator and test instruments are standard, modular rack mounting.

Environmental

Cleanliness level—Equivalent to terrestrial laboratory in Sortie lab. Equivalent to class 100,000 clean room external.

Temperature Constraints—Rack equipment 0°C to 50°C; pallet mounted equipment -10°C to +55°C.

Vibration and shock—Rack equipment — 1 g from 1 to 10 Hz, and 4 g shock for 11 ms. pallet mounted equipment — unknown.

Payload Contamination Sensitivity—No special requirement.

EMI—Unknown

Orbital Characteristics

Inclination—35°

Altitude—As high an apogee as possible consistent with payload and vehicle capability to maximize mutual view period during a single pass with station in continental U.S.

Pointing accuracy— $\pm 2.5^\circ$ to a specific ground station during period of mutual visibility.

Pointing frequency—Equal to frequency of mutual visibility with one ground station in U.S.

Utilities

Data—

- Data form — digital electrical, magnetic tape paper printout.
- Data rates — 1 Mbps
- Duration — Continues for duration of mutual visibility with one ground station.
- Number of operations per day — 1 to 2
- Percent of data for real time transmission — 100%

Communications—

- Real time during mutual visibility
- Rate — 1 Mbps
- Operational voice link

Computer support—Programmed pointing of antenna toward specific ground station.

Data processing and analysis—Logging of housekeeping data of instrument performance.

Other support—none

Crew Support

Number and skills—1 test engineer

Functions—Operate instrumentation, set parameters, change configuration

Duty cycle—On duty only during data periods — max 8 hours per day

Single Shift Operation—

Mission

Frequency of flight—1 per 3 mos.

Flights required—2

Mission Duration—5 to 7 days

Deployment and retrieval—none

Resupply/revisits—none

Ground Operations Support

Prelaunch checkout—1 hour, time not critical

Prelaunch constraints—none

Pad access—Same as Sortie lab

Special cleanliness—none

APPENDIX B

SHUTTLE LAUNCHED COMMUNICATIONS & NAVIGATION PAYLOADS DESCRIPTION

Mission Name	Wt. (KG.)	Orbit	Purpose
<u>R&D/Proto. Flt.</u> Communications R&D	1-2,000	Geosynchronous	Advanced Com. Technology Developments
Disaster Warning	300-1,000	Geosynchronous	Obtain Disaster Info. & Broadcast to Inhabitants
System Test Satellites	1-2,000	Geosynchronous	Proto-Flight of Planned Operational Com. & Nav. Satellites
Tracking & Data Relay Satellite	300-500	Geosynchronous	Advanced Satellite Communications Relay and Tracking

MISSION MODEL 1979-1990

Mission	79	80	81	82	83	84	85	86	87	88	89	90
<u>R&D/Proto. Flt.</u>												
Communications R&D/ATS		1	1				1	1			1	1
Disaster Warning		1	1				1					1
System Test Satellites/Operational Prototypes		1	1	1	1		1		1	1		1
Tracking & Data Relay					3					3		

APPLICATIONS TECHNOLOGY SATELLITE (ATS)
H&I/COMMUNICATIONS R&D

ATS H/I is the next step in NASA's Applications Technology Satellite Program to develop the technology and systems for future communications and navigation operational satellites. ATS H/I will continue to advance space satellite technology by proving the feasibility of high-power satellite communications to multiple regions on the Earth. The previous ATS programs furnished space facilities for user experiments in education, health care, and cultural enrichment. For example, ATS spacecraft have been used for education experiments in Alaska and Hawaii and health care experimentation in Alaska. ATS F, to be launched in 1974, will be used by the government of India for a year to broadcast family planning and farming instruction to 5000 remote villages. The emphasis of ATS H/I will be toward fulfilling potential user experimental needs in areas such as: education distribution and exchange, remote health care information and interactive communications.

The ATS H/I configuration's (shown by the artist's conception, (Figure B-1)) main features are the large solar array panels to provide about 5 kilowatts of electric power to the extensive communications systems on board the spacecraft. These panels will rotate so as to be always facing the Sun. Ion thrusters will probably be used to obtain accurate beam pointing and satellite location over a 5-year life. The high-power amplifier system on board the spacecraft will have very high efficiencies. The satellite will have a multibeam, multi-channel capability. The two large antennas on the spacecraft will allow broad and spot-beam coverages simultaneously to a number of distinct areas.

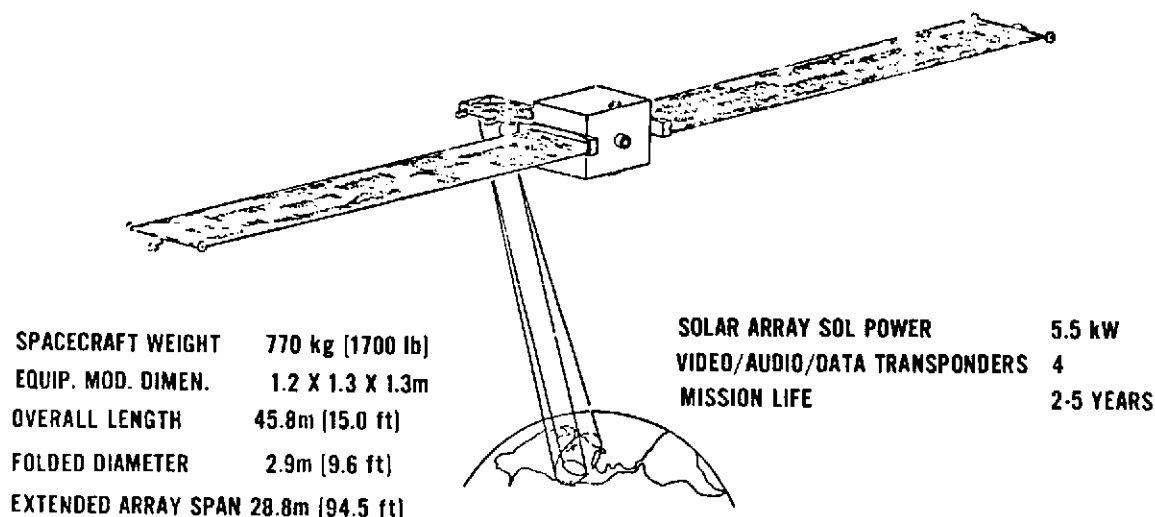


Figure B-1. ATS - Advanced Mission Spacecraft II (Direct Ascent - SLV3D/Centaur D-1A/Burner II Launched) Sun Oriented

The spacecraft will weigh about 2500 pounds in orbit and have a useful lifetime of 2-3 years for NASA experiments. Initial planning calls for launch of these satellites in the 1978-81 time period.

TRACKING AND DATA RELAY SATELLITES (TDRS)

The TDRS system is to provide nearly continuous real-time tracking and data acquisition service for satellites in near-earth orbit (up to 5,000 Km altitude). A major element of the system consists of two geostationary satellites, plus an on-orbit spare, to relay radio frequency signals received from various lower altitude spacecraft, including the space Shuttle, to earth stations in the continental U.S. In addition the TDRS will provide range and range-rate information of these lower altitude satellites to ground stations for tracking purposes, and transmit ground generated commands and voice to these satellites.

A TDRS will consist of broad band, multiple access frequency communications repeaters, appropriate antenna systems, electrical power from solar cells and batteries, and a three-axis control system. Each satellite will weigh about 440 kg. It will contain UHF, S-band and Ku-band communications subsystems for low, medium and high data rate users. A 30 element S-band array is being considered to provide up to 20 simultaneous users working with each TDRS, and a 3.8 meter erectable dish antenna for a 200 MHz channel for wide-band, Ku-band use.

The initial TDRS system is in the planning stage and is scheduled for a 1978-79 launch of three spacecraft using the Thor-Delta launch vehicle. A second generation TDRS system is in planning for launch in 1983 using the Space Shuttle transportation system. These spacecraft will be somewhat heavier and provide an increase in solar power, but will consist of similar communications and tracking subsystems. An artist's concept of the second generation TDRS for the Shuttle time period (Figure B-2) is below.

DISASTER WARNING SATELLITE (DWS)

The Disaster Warning Satellite system will use a communications type satellite to selectively broadcast disaster warnings. These warnings will be used as: a means for alerting the general public as to what to do when a disaster strikes; broadcast of weather forecasts and environmental information; and a system for collecting data and feedback information upon which decisions to issue warnings are based.

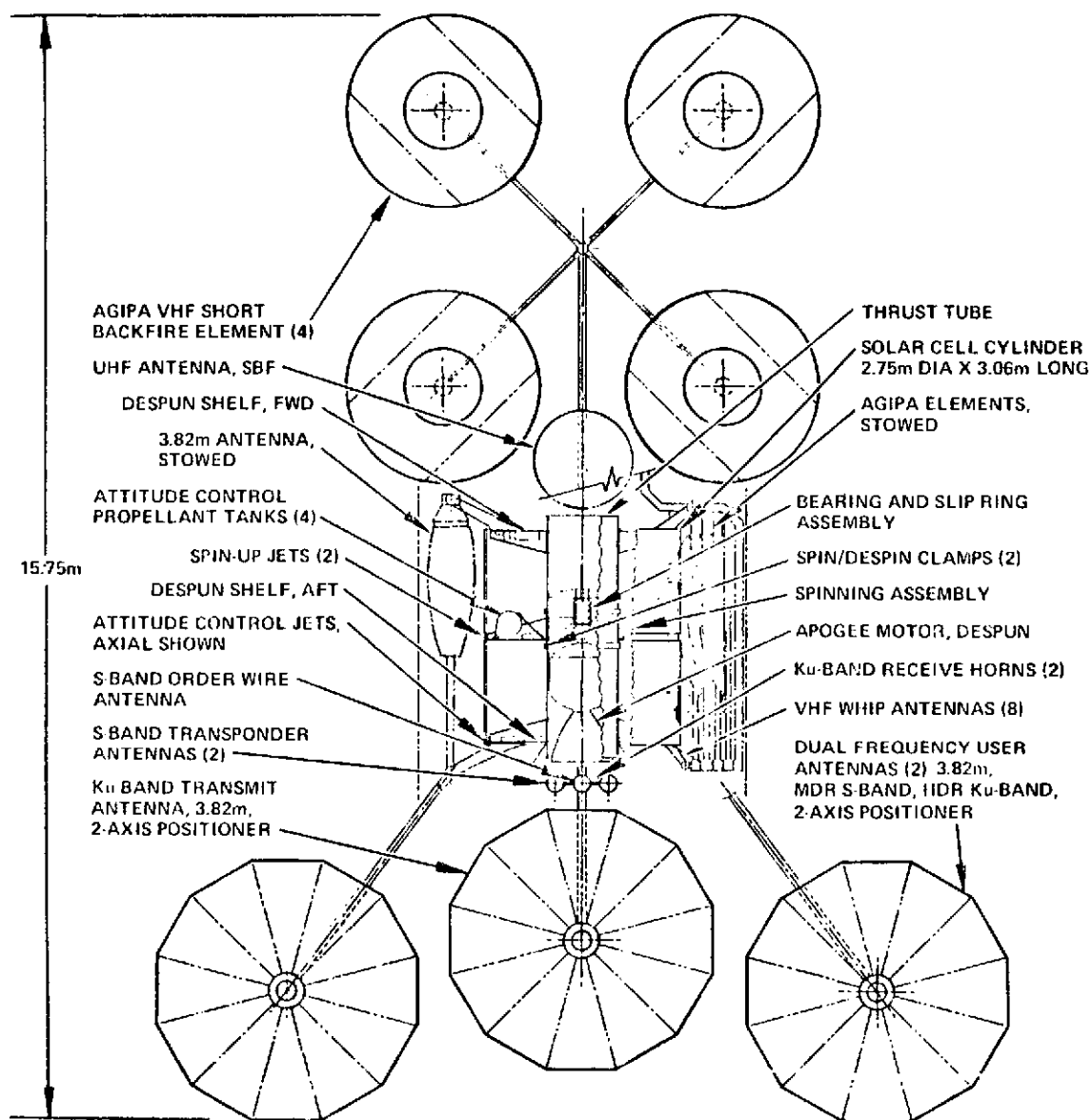


Figure B-2. TDRS Space Shuttle Configuration Baseline Design

The DWS system will consist of two geostationary orbit satellites weighing about 1500 pounds. About 5 kilowatts of dc power is to be provided by a solar cell-battery combination. The spacecraft transmitters will consist of crossed-field amplifiers operating at about 1.5 kilowatts of power in the 900 MHz frequency band. The transmitter output will be beamed to earth by using about a 19 foot parabolic antenna.

Initial planning calls for two DWS's in the 1980-81 time period and additional ones in 1985 and 1990. Added spacecraft will be a function of lifetime and utility.

APPENDIX C

SHUTTLE LAUNCHED COMMUNICATIONS & NAVIGATION PAYLOADS DESCRIPTION NON-NASA MISSIONS

Mission Name	Wt. (KG.)	Orbit	Purpose
<u>Operational</u> International Comsat	1-2,000	Geosynchronous	Intercontinental Commercial Communications
U. S. Domsat	1-2,000	Geosynchronous	Commercial Communications for U. S. Domestic Service
Traffic Mgmt	200-1,000	Synchronous	Com. & Nav. Service for Ships and Aircraft
Foreign Domsat	1-2,000	Geosynchronous	Commercial Communications for Foreign Gvt. Domsat Service

MISSION MODEL 1979-1990												
Mission	79	80	81	82	83	84	85	86	87	88	89	90
<u>Operational</u>												
International Comsat	2	3			2	3	2	2			2	3
U. S. Domestic Satellite	1	1	2	2	1	1	1	2	2	3	2	2
Traffic Management	1	2	2	1	1	1		1		1		1
Foreign Domsat		1	2	2	1	2	2	1	1	2	2	2

C-1

The following are the contents of each volume of this series:

EXECUTIVE SUMMARIES

VOLUME 1 — ASTRONOMY

VOLUME 2 — ATMOSPHERIC AND SPACE PHYSICS

VOLUME 3 — HIGH ENERGY ASTROPHYSICS

VOLUME 4 — LIFE SCIENCES

VOLUME 5 — SOLAR PHYSICS

VOLUME 6 — COMMUNICATIONS AND NAVIGATION

VOLUME 7 — EARTH OBSERVATIONS

VOLUME 8 — EARTH AND OCEAN PHYSICS

VOLUME 9 — MATERIALS PROCESSING AND SPACE MANUFACTURING

VOLUME 10 — SPACE TECHNOLOGY